



## Preoperative and postoperative shoulder position sense in patients who underwent arthroscopic Bankart repair for traumatic shoulder joint instability



Yoshifumi Tsuda, MD, PhD <sup>a,\*</sup>, Masatoshi Amako, MD, PhD <sup>b</sup>, Kenichi Takashima, MD <sup>c</sup>, Masahisa Kawaguchi, MD, PhD <sup>d</sup>

<sup>a</sup> Department of Orthopaedic Surgery, Minamitama Hospital, Tokyo, Japan

<sup>b</sup> Department of Orthopaedic Surgery, National Defense Medical College, Saitama, Japan

<sup>c</sup> Department of Orthopaedic Surgery, Japan Self-Defense Forces Sapporo Hospital, Sapporo City, Japan

<sup>d</sup> Department of Orthopaedic Surgery, Japan Self-Defense Forces Central Hospital, Tokyo, Japan

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**Background:** Proprioceptive feedback is a reflex dislocation prevention mechanism that contributes to shoulder joint stability. In patients with Bankart lesions, the anteroinferior glenohumeral ligament complex is damaged and reduces the likelihood of tensile stress. As a result, proprioceptive feedback does not work, which leads to instability. Surgical reconstruction is indicated to restore proprioception, but the details of recovery after arthroscopic surgery are unknown. The purpose of this study is to investigate whether arthroscopic Bankart repair can improve the position sense of the shoulder.

**Methods:** We used the isokinetic dynamometer Biodex System 3 (Biodex, Shirley, NY, USA) to investigate preoperative and postoperative joint position sense in 140 shoulders (137 men, 3 women) undergoing arthroscopic Bankart repair for traumatic shoulder joint instability. The control subjects comprised 40 shoulders of healthy volunteers (all men). Active position sense was measured by setting the shoulder external rotation to 75° based on 90° abduction and neutral internal/external rotation position. Reproductive angle inaccuracy (RAI) was measured thrice, and the mean value was calculated. The RAI was measured preoperatively, 6 months and 1 year postoperatively, and at the final observation (range, 16–96 months; mean, 31.5 months).

**Results:** Mean RAI was significantly higher (6.4°) preoperatively in the traumatic shoulder instability group than in the control group (5.0°). Mean postoperative RAI changed to 5.0, 4.9, and 4.7° at 6 months, 1 year, and final observation, respectively (mean, 31.5 months). RAI recovered to the same level as the control group at 6 months after the surgery and was maintained the same level until final observation.

**Conclusion:** Position sense was significantly worse in patients with traumatic shoulder joint instability than in healthy volunteers, and a significant improvement in position sense was observed after reconstruction of the anteroinferior glenohumeral ligament complex by arthroscopic Bankart repair. Therefore, arthroscopic Bankart repair is a favorable procedure that can improve the position sense of the shoulder in patients with traumatic shoulder instability.

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Afferent sensory nerve fibers are concentrated in the anteroinferior glenohumeral ligament (AIGHL) complex of the shoulder joint and they play an important role in controlling the joint proprioception such as position sense and motion sense.<sup>5,16</sup> When the shoulder joint reaches an excessive abduction/rotational position,

that is, the most dangerous position where dislocation is likely to occur, tensile stress applied to the AIGHL complex stimulates mechanoreceptors of afferent axillary nerve, causing reflex contraction of the shoulder joint muscles around the rotator cuff.<sup>9</sup> Lephart et al.<sup>9</sup> referred to this reflex dislocation prevention mechanism as proprioceptive feedback and considered it an important mechanism contributing to shoulder joint stability. In patients with Bankart lesions, injury to the capsuloligamentous structures may result in an inability of the stretch receptors to recognize that an end range of motion or dangerous position is being approached, which results in a failure to signal the dynamic stabilizers to

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\* Corresponding author: Yoshifumi Tsuda, MD, PhD, Department of Orthopaedic Surgery, Minamitama Hospital, 3-10-1 Sanda, Hachioji-city, Tokyo, 193-0832, Japan.  
E-mail address: [nekoure\\_13@yahoo.co.jp](mailto:nekoure_13@yahoo.co.jp) (Y. Tsuda).

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stabilize the shoulder joint. Thus, if the capsuloligamentous structures are pathologically lengthened, the normal neuromuscular feedback mechanism may no longer be operative, predisposing the shoulder to instability.

It has also been recently shown that surgical stabilization may restore proprioception to the shoulder,<sup>9,13</sup> but little is known about how this may occur. The best type of surgical reconstruction would be restoring the Bankart lesion with preserving proprioceptive structures and mechanoreceptors. We suggest that arthroscopic Bankart repair is most suitable for restoring capacitance of the capsule because it does not cut the capsule and least violates the nerve fiber and mechanoreceptors. But details of recovery of the proprioception after the arthroscopic Bankart repair are not known. The purpose of this study is to investigate whether arthroscopic Bankart repair can improve the position sense of the shoulder.

## Materials and methods

Isokinetic dynamometer Biodex System 3 (Biodex, Shirley, NY, USA) is used not only to measure muscle strength torque and angular velocity during joint exercise, but also to evaluate the position sense of a joint, which is a type of proprioception, by setting a target angle and causing the subject to reproduce it. We used the Biodex System 3 to measure the position sense in patients with traumatic shoulder joint instability who underwent shoulder arthroplasty by arthroscopic Bankart repair. We compared the preoperative and postoperative changes in position sense in these patients with those in healthy volunteers. This prospective study included 140 patients (137 men, 3 women; mean age, 26.3 years; range 18–48 years; 76 right and 64 left shoulders) who underwent arthroscopic Bankart repair for traumatic shoulder joint instability in our department between 2004 and 2016 and for whom follow-up could be performed for  $\geq 1$  year postoperatively. All of the patients were the JAPAN Self-Defense Force personnel. Patients with a rotator cuff injury, a humeral avulsion of the glenohumeral ligament lesion, and a joint bursal fracture were excluded from this study to investigate only the effect of single Bankart lesion. All patients underwent arthroscopic Bankart repair by multiple surgeons with the same procedure. Any labral detachment, that is, a Bankart lesion, was repaired using suture anchors with arthroscopic tying techniques. A rotator interval was added as a capsular plication for repair of any existing capsular redundancy. Postoperative treatment, consisting of shoulder abduction brace fixation (UltraSling, DonJoy, Vista, CA, USA), was performed for 3 weeks. Under the physical therapist's guidance, passive motion exercise and active motion exercise were initiated 1 and 2 weeks postoperatively, respectively. After discharging, we made all patients come to our outpatient clinic every two weeks to control for exposure compliance of postoperative rehabilitation until 3 months after surgery. All activities of daily living were permitted at 3 months and all sports were permitted at 6 months postoperatively, respectively. In addition, 20 healthy male volunteers with no shoulder joint disorder (mean age, 25.7 years; range 20–35 years; 20 right and 20 left shoulders) were included as a control group, and position sense of both shoulders was measured. Postoperative functional evaluation was performed using the Japan Shoulder Society (JSS) Shoulder Instability Score, JSS Shoulder Sport Score, Japan Orthopedic Association score, Rowe score and University of California at Los Angeles Scale. Moreover, Shoulder 36 v.1.3 was used for objective functional evaluation. These assessments were administered preoperatively, 6 months and 1 year postoperatively, and at the final observation (range, 16–96 months; mean, 31.5 months). Postoperative redislocation was observed in 6 (4.3%) out of 140 shoulders, and these patients were excluded from this study.



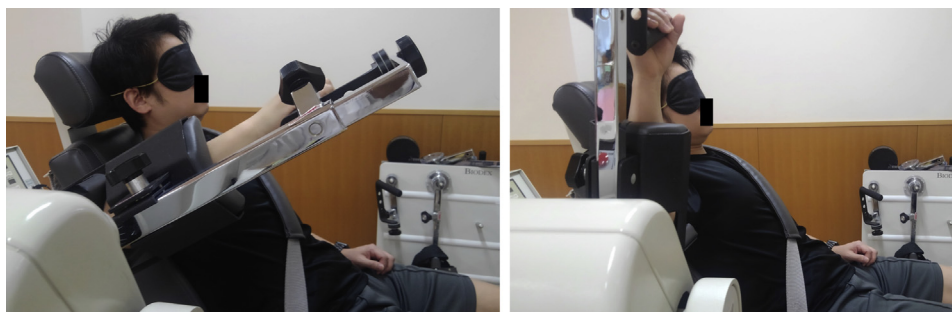
**Figure 1** Measurement of position sense using the Biodex System 3. The trunk of the patient was fixed with a seat belt and the patient was blindfolded to prevent visual assistance.

The position sense was evaluated using the Biodex System 3 to measure the reproductive angle inaccuracy (RAI) or the error in the target angle: the smaller the value, the higher the position sense accuracy. The trunk of the patient was fixed with a seat belt to stabilize the scapula and patients were blindfolded to prevent visual aid (Fig. 1). An external rotation angle of  $75^\circ$  was set as the target angle based on shoulder joint  $90^\circ$  abduction/neutral internal/external rotation position (Fig. 2). In actual measurement, after ensuring that the patient is aware of the target angle position once in the blinded state, the patient was asked to return to the reference position of neutral internal/external rotation position and press a switch button with the opposite hand when they were aware that the shoulder had externally turned and reached the target angle. The error between the actual angle at that time and the target angle of  $75^\circ$  was measured as RAI. RAI was measured thrice, and the mean value was calculated. To avoid muscle fatigue, about a 1-minute break was set between three trials. Before measurement, the Biodex limiter was set to the patient's maximum external rotation angle. It was ensured that the shoulder joint did not reach excessive external rotation during the measurement. The RAI was measured preoperatively, 6 months and 1 year postoperatively, and at the final observation (range, 16–96 months; mean, 31.5 months). For statistical analysis, statistical software JMP pro 13 (SAS Institute Inc., NC, USA) was used for one-way analysis of variance (ANOVA), and the post hoc multiple comparison test was conducted by the Tukey-Kramer method. The significance level was set at 5%.

## Results

On functional evaluation, there was significant improvement in the JSS Instability, the JSS Sport, Japan Orthopedic Association, Rowe, and University of California at Los Angeles scores at 6 months, 1 year, and final observation, respectively (Table I). On Shoulder 36 v.1.3 testing, significant improvement was noted for all items of pain, range of motion, muscle strength, feeling of health, activities of daily living, and sports at 6 months, 1 year, and final observation, respectively (Table II).

Mean RAI  $\pm$  standard deviation was  $5.0^\circ \pm 2.1^\circ$  in the control group and  $6.4^\circ \pm 3.8^\circ$  preoperatively in the patient group ( $P = .03$ ; Fig 3). The postoperative change in mean RAI in the patient group is shown in Table III ( $6.4^\circ \pm 3.8^\circ$ ,  $5.0^\circ \pm 3.7^\circ$ ,  $4.9^\circ \pm 2.5^\circ$ , and  $4.7^\circ \pm 2.5^\circ$  preoperatively, at 6 months and 1 year postoperatively, and at final observation, respectively). Compared with the preoperative values, significant differences were observed at 6 months and



**Figure 2** (Right) Based on 90° shoulder abduction and neutral internal/external rotation position, (Left) the external rotation angle of 75° was set as the target angle.

**Table I**  
Functional scores

	Pre	6 mo	1 y	Last
JSS instability	60.3 (14.6)	86.0 (9.1)*	88.8 (8.5)*	88.6 (10.3)*
JSS sport	56.4 (18.9)	69.2 (15.6)*	77.6 (14.7)*	81.9 (16.2)*
JOA	76.6 (11.7)	93.5 (5.8)*	95.0 (5.4)*	95.7 (5.1)*
Rowe	38.5 (18.1)	92.0 (8.0)*	93.6 (10.5)*	94.2 (9.4)*
UCLA	19.7 (3.7)	27.0 (2.7)*	27.8 (2.1)*	28.3 (3.1)*

JOA, Japan Orthopedic Association; UCLA, University of California at Los Angeles; JSS, Japan Shoulder Society.

The average values, standard deviation (SD) are shown.

\*  $P < .01$ .

**Table II**  
Objective functional scores

	Pre	6 mo	1 y	Last
Pain	3.7 (0.5)	3.9 (0.2)*	3.9 (0.2)*	3.9 (0.1)*
ROM	3.7 (0.5)	3.9 (0.2)*	3.9 (0.2)*	4.0 (0.1)*
Power	3.4 (0.8)	3.9 (0.3)*	3.9 (0.3)*	3.9 (0.2)*
General health	3.8 (0.3)	3.9 (0.2)*	3.9 (0.2)*	4.0 (0.1)*
ADL	3.8 (0.4)	3.9 (0.2)*	4.0 (0.2)*	4.0 (0.1)*
Sports	2.3 (1.1)	3.2 (0.8)*	3.3 (0.7)*	3.5 (0.8)*

The average values and standard deviation (SD) are shown.

\*  $P < .01$ .

1 year postoperatively and at final examination ( $P = .0017$  by 1-way ANOVA;  $P = .003$  at 6 months and 1 year postoperatively, and  $P = .02$  at the final examination by post hoc).

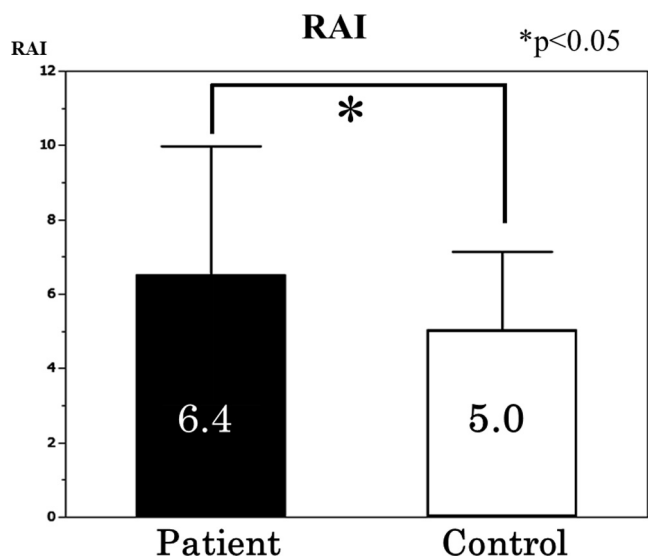
**Discussion**

Our study showed that position sense was significantly lower in patients with traumatic shoulder joint instability than in healthy volunteers. A significant improvement in position sense was observed after reconstruction of the anteroinferior glenohumeral ligament complex by arthroscopic Bankart repair.

Anterior and inferior joint branches of the axillary nerve are distributed in the AIGHL complex of the shoulder joint.<sup>5</sup> Nerve axons and mechanoreceptor Pacinian corpuscles have been identified in the synovial layer at the shoulder labrum—joint capsule junction.<sup>6,16</sup> They are afferent sensory nerve fibers that control and transmit proprioception, such as a joint position sense or a motion sense to the central nervous system.<sup>2,7,9,10</sup>

After surgery for traumatic shoulder instability, some patients continue to be apprehensive of using the shoulder joint despite the anatomical repair of a Bankart lesion and sufficient recovery of postoperative muscle strength. This may be due to the insufficient recovery in proprioception.

Previously, shoulder proprioception was measured using original devices.<sup>3,7,9,12,18</sup> For example, Jerosch et al<sup>7</sup> measured the angle by photographing with a charge coupled device camera from the side with fluorescent markers attached to the elbow and wrist joints of the subject. By contrast, this study used an isokinetic dynamometer, the Biodex System 3, which is a highly versatile and commercially available device that can be used by multicenter research groups. Although several articles used the isokinetic dynamometer to assess the shoulder position sense, we developed our own method of measurement in this study<sup>15</sup> to obtain more accurate data in the shoulder joint position where tensile stress applied to the AIGHL complex to stimulate mechanoreceptors. Based on 90° shoulder joint abduction and neutral internal/external rotation position, 75° external rotation was set as the target angle, and adjustments were made so that the AIGHL tension could be obtained easily. The reason for setting the target angle to 75° was to avoid the risk of dislocation during measurement. The angle of the Biodex System 3 can only be set in 15° increments, and setting the target angle to 90° approaches a position at which there is a risk of dislocation. However, the range of external rotation naturally differs in each patient; whether it is appropriate to uniformly set the target angle at 75° is arguable. Blasier et al<sup>3</sup> reported that the accuracy of a position sense is improved as the limit of the range of external rotation is approached, whereas Jerosch et al<sup>7</sup> reported that sense at 60° external rotation was more accurate than that at 90° external rotation. Future studies are needed to



**Figure 3** Comparison of RAI between preoperative patient group and control group. The graphs show average values and error bars mean standard deviation (SD). RAI, reproductive angle inaccuracy.

**Table III**  
Preoperative and postoperative RAI

	Pre	6 mo	1 y	Last
RAI	6.4 (3.8)	5.0 (3.7)*	4.9 (2.5)*	4.7 (2.5) <sup>†</sup>

RAI, reproductive angle inaccuracy.

The average values and standard deviation (SD) are shown.

\*  $P < .01$ .<sup>†</sup>  $P < .05$ .

determine the appropriate angle of external rotation. The testing procedures were repeated thrice, and the average was measured as reported previously.<sup>1,4,14</sup> Increasing the number of measurements further will lead to muscle fatigue and reduce the position sense accuracy.<sup>17</sup>

Consistent with previous studies,<sup>9,13</sup> our results indicate that the position perception was significantly lower in patients with traumatic shoulder instability than in normal subjects. Rokito et al<sup>13</sup> reported that 12 months were required for postoperative recovery after examining 2 types of open surgery: capsular shift by Neer's method<sup>11</sup> and shoulder labrum reconstruction by Jobe's method.<sup>8</sup> Our results revealed that RAI recovered to the same level as that in healthy volunteers from 6 months postoperatively and was maintained until the final observation. Based on the literature data, it is probable that arthroscopic surgery could improve the postoperative position sense of the shoulder joint 6 months faster than open surgery. As mentioned previously, mechanoreceptors in the anterior-posterior joint capsule branch of the axillary nerve are concentrated mainly in the synovial layer at the border between the labrum and joint capsule and not in the labrum and cartilage.<sup>6,16</sup> Open Bankart repair has a high risk of damaging the neural sensory branches because of cutting the joint capsule, whereas the arthroscopic Bankart repair has a low risk of nerve damage because it is a technique to pull up the labrum and AIGHL without cutting the capsule. Therefore, we believe that the arthroscopic Bankart repair, through which the mechanoreceptors were conserved, led to faster recovery of proprioceptive feedback than open Bankart repair. Blasler et al<sup>3</sup> reported that capsular tightness is important for proprioception, and our technique of adding rotator interval closure to arthroscopic Bankart repair seems reasonable as the joint capsule is sutured to increase tension.

However, the difference between RAI preoperatively and 6 months postoperatively was approximately 1°, and while the difference is statistically significant, the clinical difference is unclear. Lephart et al<sup>9</sup> reported that the preoperative difference between the affected and healthy sides was small (1°–2°), and in high-level athletes in particular, the difference of 1° may be significant.

A limitation of this study is that we did not compare patients in accordance with the endoscopic classification of the AIGHL complex. Our patients comprised mainly young men (mean age, 26.3 years) with traumatic shoulder instability, and in most patients, AIGHL was relatively good. However, despite performing the same procedure, sufficient suturing effect may not have been achieved in cases where AIGHL was loose or hypoplastic. Because the conditions of preoperative AIGHL may change the recovery of proprioceptive feedback, future cases should be examined according to the grade of the AIGHL complex.

## Conclusion

The present study showed that preoperative position sense was significantly lower in patients with traumatic shoulder instability

than in healthy volunteers. The position sense after arthroscopic Bankart repair was significantly better at 6 months postoperatively than that preoperatively, and the trend in improvement was maintained till the final observation. Therefore, arthroscopic Bankart repair is a favorable procedure that can improve the position sense of the shoulder in patients with traumatic shoulder instability.

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